The Progress of Surgery as Influenced by Vivisection

BY

W. W. KEEN, M. D., LL. D.,

Professor of the Principles of Surgery and of Clinical Surgery,

Jefferson Medical College, Philadelphia.

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Reprinted from "The Philadelphia Record" of September 14 and 21, 1901.

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PART 1

I have been asked by the editor of "The Philadelphia Record" to write a brief resume of the influence of vivisection on the progress of modern surgery. I shall do so as briefly as I possibly can, stating only facts which are generally well known to surgeons, but of which the general public of necessity must be ignorant to a great extent. Most of the facts below stated are known to me personally, as they have occurred during my professional lifetime; and I can, therefore, vouch for their accuracy.

If a physiologist were asked to contribute a similar paper he would be able to tell a similar story as to the revelations of the functions of various organs in the human economy obtained through vivisection; if a professor of pharmacology (i. e., the action of drugs upon the living body) were to write a similar paper he would be able to show an equal debt owing to animal experimentation, first in giving us an exact knowledge of the action of drugs, and, secondly, in the introduction of a large number of new drugs. In this way cocaine was introduced into medicine and the proper use of such a powerful drug as digitalis was shown.

If a medical man were to write a similar chapter he would scarcely know where to begin. The whole life history, for example, of the trichina has been studied in animals and the results applied to man, so that if every one would heed the warning no one need die from the trichina worm in pork. This has had also an enormous commercial value, since all our hog products are exported on condition that the trichina be excluded by microscopical examination. In diphtheria the percentage of deaths has been reduced in Baltimore from about 70 per cent. to about 5 per cent. The saving of human life in a single year in

New York has been 1500. All this is due to the antitoxin of diphtheria, which has been evolved almost solely as a result of animal experimentation.

Two water companies in London in 1853 experimented on 500,000 human beings, and, as a result of the cholera, one of them killed 3476 human beings. In that same year Thiersch, in Leipzig, experimented on fifty-six mice. Had the lesson of these few mice been heeded the lives of these human beings might have been saved. More than that, even at the present day, as a result of Koch's discovery of the cause of cholera, Haffkine, in India, is making protective inoculations which are proving of the greatest value. By the same method we have recently discovered that the bubonic plague is spread by rats, and that efficacious vaccines can be used against this dreadful disease; that the malarial parasite is spread by mosquitoes, as proved by studies both in birds and in human beings; and the preventive inoculations against typhoid (as yet in the early stage of their use) have been discovered by the same means.

On the border line between medicine and surgery is the new science of bacteriology. In surgery this has shown the cause of erysipelas, of inflammation, of tetanus or lock-jaw, of glanders, of tuberculosis (not only of the lungs, but of the brain, the bones, the joints, the bowels, etc.) and of many other disorders.

Let me give one illustration of the method by which the cause of one disease—tuberculosis—was proved. Similar methods are employed in tracing the causes of others. In a case of consumption of the lungs the expectoration is examined by the microscope after applying a staining material. Without staining the tubercle bacilli are so translucent (like little rods of jelly) that we can scarcely see them. Having found this peculiar germ in the expectoration, some of the material is injected under the skin of a guinea pig. After a certain time the animal either dies or is killed, and a post-mortem examination is made. If there are found in the body of the guinea pig little nodules—i. e., tubercles (little tubers)—these are examined by the same method and the same germs will be discovered and can be obtained in a pure culture. But the circle of proof is not yet complete. A small portion of this pure culture of the germs obtained from the inoculated guinea pig is again injected into another animal, and if the second animal suffer from a similar disease and the same germ be found again the conclusion is irresistible that the cause of the tuberculosis is the peculiar germ always found in such cases.

I well remember the incredulity with which I first read of the origin of lock-jaw from the soil, but very soon this incredulity was changed to belief in the face of absolute demonstration after this fashion: It had been well known for years that hostlers, cavalrymen, farmers and persons who were engaged in any occupation about horses were peculiarly liable to lock-jaw. After the discovery of the bacillus of lock-jaw in 1884, by Nicolaier, when a case of lock-jaw occurred, the ground on which the patient had fallen, or the instrument by which he had been hurt, was examined, and a certain bacillus was found in or on it. This was inoculated into animals, and was found to produce the same disorder; and the same

bacillus was recovered from the animal's body, and was reinoculated. The circle of proof, therefore, was complete. This explained the popular belief that treading on a rusty nail is a frequent cause of lock-jaw; not because it was a nail or old or rusty, but because the germ of lock-jaw was on it and in the ground in which it was lying. No such exact experiments are justifiable on man. The sacrifice of a few rats quickly gave us all the desired information. This has abolished lock-jaw as a result of surgical operations, and enabled us to cure it in many cases even after accidental inoculation. Before 1884 it was both frequent and fatal; now it is almost a surgical curiosity, except after neglected accidents.

The two most important surgical discoveries of the Nineteenth Century were, (1) anesthesia, especially by ether (in 1846) and by chloroform (in 1847); and (2) antisepsis, by Lord Lister, who began his work soon after the middle of the Nineteenth Century and had distinctly formulated it about the end of the 60's. His remarkable paper in The Lancet of April 3, 1869 (when he was simply Mr. Lister, Professor of Surgery in the University of Glasgow), was one of those papers which marked a new era in surgery. Several years before he had announced that he believed that inflammation and most of our surgical disorders were due to germs, and that if we could exclude these germs we would be able to secure the healing of wounds without inflammation and without the formation of pus (matter); yet it was not until 1881 that Ogston and Rosenbach discovered the germs which produce the terrible results of inflammation, such as erysipelas, hospital gangrene (what irony in the name!) abscesses, blood poisoning and even death.

HEMORRHAGE.

One of the most important contributions by Lister to the progress of surgery was the introduction of antiseptic threads (ligatures) of catgut, with which to tie blood vessels. One of the earliest Philadelphia surgeons, Philip Syng Physick, tried to get rid of the dangers following silk, which had been used to tie arteries ever since Ambroise Pare introduced it in the Sixteenth Century as a happy substitute for the horrible hot pitch and hot iron which then were the only means for arresting hemorrhage. Physick sought to use buckskin, on the ground that it was an animal substance and would, therefore, disappear by absorption. Dorsey used catgut. Hartshorne used parchment cut in fine threads, and Bellinger and Eve the tendon of the deer. But none of these surgeons succeeded in giving us harmless ligatures until Lister taught us how to use them. In the paper which I have referred to he showed that the old idea of a ligature was that it was a foreign body which was to be got rid of by its rotting through the walls of the blood vessel. The result was that in a very large percentage of cases the blood vessel was not stopped by a clot; secondary hemorrhage took place (usually during the second week after an operation), and many a patient bled to death.

I shall never forget one night in the Satterlee Hospital, of West Philadelphia, about ten days after the battle of Gettysburg, when I was called five times to check just such secondary hemorrhage from the rotting through of silk liga-

tures. As a consequence of the introduction of antiseptic ligatures by Lister I do not recall in the last twenty years five cases similar to these five that I then attended in one night. In other words, secondary hemorrhage has almost disappeared from surgical experience.

How did Lister find out the proper method of tying an artery? On December 12, 1867, he tied the great carotid artery in the neck of a horse with a piece of pure silk saturated with a strong watery solution of carbolic acid, cutting both ends of the thread short and dressing the wound antiseptically. Healing took place without any inflammation. Six weeks after the operation he investigated the parts by dissection, and found that if the thread had not been applied with the antiseptic precautions secondary hemorrhage would unquestionably have occurred, and in all probability the animal would have bled to death. On January 29, 1868, he applied this principle in the case of a woman of fifty-one with an enormously dilated sac (an aneurism) in the upper part of the great artery supplying the thigh and leg. She, like the horse, recovered without inflammation, and lived for ten months. On November 30 she suddenly died as the result of a rupture of a similar dilatation of the aorta in the chest. This gave Lister the unusual opportunity of examining in a human body the result of his application of an antiseptic thread to the arteries. The case emphasizes one of the great difficulties in studying such questions on human beings. The opportunity for a post-mortem examination after such an application of a new principle can only be occasional. If this woman at the time of her death had been under the care of some other surgeon than Lister no such careful examination of the consequences of the tying of the artery would have been made, and no further progress would have followed. The result of his examination showed that, in spite of his care, an incipient abscess was developing at the point at which he had tied the artery. This was in consequence of the presence of the thread, and especially of the knot.

As a result of this investigation, on December 31, 1868, he tied the carotid artery in the neck of a calf with catgut which had been prepared with carbolic acid, and all antiseptic precautions were used during the operation. The calf recovered perfectly, and in thirty days was killed and the parts dissected. He found that at the site of the thread of catgut there was a band of living tissue surrounding the thread and closing the artery, and that, therefore, instead of the thread rotting through, as was the case with the silk, it had become a part and parcel of the tissues. The artery, instead of being so weakened as to allow of secondary hemorrhage, was really stronger at this point than at other points. The ligature and the knot had entirely disappeared.

I have narrated this somewhat in detail for this reason: It illustrates admirably the method of scientific progress by experiment upon animals. Neither of these animals suffered any material pain, both operations having been done with the same antiseptic care as in a human being. Both of them were killed at such a time as would facilitate our knowledge of the results.

Since then other experimenters have tied the blood vessels in animals and have killed them at varying intervals and made microscopical examinations of

the blood vessels. In this manner our knowledge of the way in which hemorrhage is stopped is now complete. The knowledge which was attained within a short time by the sacrifice of a few animals would have been attained only after many years by occasional post-mortems, and would then have been very much less perfectly attained and only by the loss of many human lives instead of a few animals' lives.

Contrast, now, the result of the old and the new surgery in the mere matter of stopping hemorrhage after operations or accident by tying blood vessels with the old ordinary silk and the modern antiseptic catgut, or with silk itself as now used by improved methods. In the old way the blood vessels were tied with silk, which was as clean as an ordinary housewife would have it. One end was left long, and it was no uncommon thing after an amputation of the thigh to have as many as twenty or thirty of these ligatures or threads hanging out of the wound. After two or three days, when those on the smaller blood vessels would, possibly, be rotted through, each ligature was pulled upon, and those that were already loosened by putrefaction came away. Finally, at the end of ten days, two weeks or three weeks, the ligature on the great blood vessel of the arm or thigh came away, not uncommonly followed, as has been stated, by profuse and often fatal hemorrhage. Sometimes, as in Lord Nelson's case, such a ligature did not rot away for years, and required dressing of the arm all of this time on account of the constant discharge.

What happens to-day in a surgical operation where either properly prepared silk or catgut is used? We tie all the blood vessels needing it, cut off both ends of the threads short and close the wound entirely; and, instead of having discharge and horrible inflammation for days and often weeks and sometimes months, it is now a rare thing for such a wound not to be entirely healed within ten days, and sometimes less, and secondary hemorrhage is almost unheard of. If vivisection had given to surgery only the modern means of stopping hemorrhage it would be worth all the labor it has required and all the suffering it has inflicted on all the animals ever experimented upon.

Of late a new problem in hemorrhage has been presented. When an artery is wounded—as, for instance, if the blade of a pocket knife has been thrust into the thigh and wounds the great femoral artery—the only way to prevent the patient's bleeding to death has been to expose the artery and tie it above and below the point where it was cut. Of late several surgeons (especially Murphy, of Chicago) have made some very ingenious experiments on such wounded blood vessels. They have carefully exposed the artery of an animal (under an anesthetic, of course), have wounded it, and then, instead of tying the artery, have sewed up the wound in the wall of the artery to see whether this could not be done successfully. The reason for this series of experiments is this: When we cut off the supply of blood to a leg or an arm by tying the blood vessel, gangrene not uncommonly occurs, because the chief blood supply of the limb is cut off by tying the artery. If instead of tying the vessel we can sew up the wall and it will heal, the current of blood is uninterrupted and there is no danger of gangrene. One thing is per-

fectly manifest—it would never be proper to make such experiments on human beings. Human life would be endangered, and no surgeon would adopt or would be justified in adopting such a novel procedure until it had been tried and proved successful on animals. Several successful cases of suture (sewing) of the large blood vessels have now been done in man.

THE BRAIN.

When I first taught anatomy, thirty-five years ago, the various portions of the brain were not supposed to have separate functions. We knew, of course, that disease or an injury on one side of the head produced paralysis on the opposite side of the body. Broca also discovered by observations on man in actual cases of disease that when that part of the brain corresponding to the left temple was affected the power of speech was lost. But if a man had a fracture of the skull or a gun-shot wound in the region above the ear or in the front of the brain or the back of the brain, there was no well recognized difference in the results. This was largely due to the fact that such injuries are widespread, and not limited to small areas. In Germany Fritsch, Hitzig and Goltz, and in England Horsley, Ferrier, Schaeffer and others, pursued the following plan: The monkey's brain is the nearest in similarity to man's. A known portion of the brain—for instance, the region above the ear—being exposed, the brain was mapped out in small squares and each one of these squares in succession had the pole of a battery applied to it. The phenomena which occurred—whether opening and shutting the eyes, turning the head right or left, contraction of the muscles of the arm or leg—were all carefully noted down. In this way a distinct map of the brain was made, so that we know definitely that a certain area of the surface of the brain governs the movements of the eyes, of the head, of the arm, forearm, hand, thumb, thigh, leg, great toe, etc. In the same way at the back of the head the area which governs sight has been found, and it was discovered that the area on the right side if destroyed made the right half of each eye blind, and that if the area of the left side was destroyed the left half of each eye became blind. This description is, probably, sufficient to indicate how physiologists and surgeons have investigated the brain.

The following is an instance which shows how accurately this method has enabled us to locate the motor centres in the brain. A girl, who suffered from epilepsy, and in whom the convulsions always began in the right thumb, and then spread to the arm and the body, was operated upon. A piece of the gray matter of the brain, as large as the last joint of the forefinger, was removed from the place determined upon animals as the centre governing the movements of this thumb. When she awoke from the ether that thumb was entirely paralyzed, and no other part of the body. When we remember that the muscles which move the thumb arise in the ball of the thumb, between the thumb and the forefinger and on the front and the back of the forearm nearly as high as the elbow, this is seen to be most remarkable. I do not know a single case ever recorded of so minutely located disease. By no other means than vivisection could this small thumb centre have been determined. She has entirely recovered from the paralysis,

and her epileptic fits instead of being almost daily were reduced to one or at the most two a year. This has made possible the modern surgery of the brain, which would not exist to-day were it not for vivisection.

Here and there an unexpected post-mortem examination, as in the case of Lister's woman patient, has given us some special information, but nine-tenths if not ninety-nine-one-hundredths of our knowledge of cerebral localization is the result of exact experiment on animals. As a consequence of this in 1884, for the first time in the history of surgery, the existence of a tumor of the brain, which was not indicated by anything on the outside of the head, was diagnosticated, its location determined and the tumor removed. When the skull was opened no tumor was visible: but so confident was Mr. Godlee, the surgeon, that he cut boldly into the substance of the brain and there found the tumor which had been so accurately diagnosticated. Since then this first achievement has been repeated not only scores, but hundreds of times, and the net result up to 1898 was that 273 brain tumors had been operated on. Of the patients 169 (61.9 per cent.) had recovered and 104 (38.1 per cent.) had died. At present it can be said that two out of every three recover! This localization of cerebral functions, together with antisepsis, has so revolutionized (or, rather, created) modern cerebral surgery that the principal facts are a matter of common knowledge. Tumors are now attacked not only in what is called the motor area (that is, that portion of the brain governing movement, which, roughly speaking, may be described as lying above the ear), but many times in the front part of the brain, and at the back of the brain, far outside of the motor area. In case the tumor is at the base of the brain, or at certain other parts this knowledge has prevented useless operations which otherwise might have been performed.

It is a source of sincere gratification on the part of numerous surgeons that by this same knowledge of cerebral localization derived from animal experimentation they have been able to recognize hemorrhage inside the skull, open the skull at the right point, even when there was no fracture, and save their patients. Before experiments on animals showed us how to interpret the symptoms this was an impossibility, and nearly all such patients died. Now we save, roughly speaking, two out of three!

Time and space would fail me to tell of the abscesses of the brain, of the foreign bodies in the brain (such as nails driven into it by accident or design, rifle balls which had lodged in it) and of many other similar surgical disorders the modern successful treatment of which depends directly upon the localization of cerebral functions, which is the result almost wholly of experiments upon animals.

THE SPINAL CORD.

Up to the present time the belief of surgeons has been that in case the spinal cord was completely cut in two, either by gunshot wounds, fracture of the spine or otherwise, no reunion of the two ends would take place, and, therefore, there was no possibility of relief for the paralysis below the point of division of the cord which is almost always fatal. Only this winter, at the Pennsylvania Hospital, Dr. Stewart had a patient whose spinal cord was cut in

two by a bullet. He removed the bone sufficiently to get access to the spinal cord, and found it completely divided. He immediately stitched the two ends together, and, strange to say, this patient has recovered both feeling and motion to some extent in both legs. I think it would be evident to any person that such a totally unexpected result deserves the most careful investigation. In man cases of such complete division followed by recovery are almost unknown; and if they had to be studied in man this would be imperfectly done, and probably would require fifteen or twenty years before we would know what ought to be done. It is one of those cases in which it is our duty to investigate by experiments upon animals what is the best method of sewing the two ends of the spinal cord together: at what date after division of the cord it will be hopeless to do so; how much of the cord can be lost (that is to say, a half inch, inch or more) and yet by stitching the two ends together it will be possible to restore the function of the spinal cord. One can see very readily that in animals all these problems can be studied minutely, in a sufficient number of cases; various procedures can be tested and the results determined accurately by killing such animals at a suitable date, and a definite conclusion can be reached in a short time.

In 1888 Mr. Horsley, the distinguished London surgeon, and Dr. Gowers, equally distinguished as a neurologist, for the first time in the history of surgery made a diagnosis of a tumor of the spinal cord, definitely located it and the former removed it, the patient making an absolute recovery. A number of other cases have been successfully operated on since then. Just as in the case of tumors of the brain, this would not have been possible had it not been for experiments upon animals, which have given us practically most of our present knowledge of the minute anatomy and physiology of the spinal cord and have, therefore, enabled us to deal with it surgically.

NERVES.

Among the most fruitful branches of research which have been so valuable in results are the animal experiments upon the different nerves of the body. The methods by which nerves could be sewed together; the possibility of taking a portion of a nerve or even of the spinal cord from a rabbit or other animal to replace a piece of the nerve when it has been destroyed by accident or disease; the possibility of sewing one nerve to a neighboring nerve in order to re-establish its function—all of these and other similar operations have been studied in animals, and could only be studied in animals with exactness.

In order to study such conditions it is not enough that the two ends of the nerve should be sewed together and then, after the wound has healed, that we should simply determine the fact that the functions of the nerve are re-established. It is necessary to know by the microscope the various steps of the process of union of the nerves—to investigate various methods of sewing them together; whether they can be overlapped, or must be applied exactly end to end; whether one end of the nerve can be split and the other inserted into it, or turned over as a flap, and so on. Evidently numerous methods can only be studied on animals. Then, when the results are known, we can apply them for the benefit of man.

THE THYROID GLAND.

One of the commonest diseases in Europe, and one that is occasionally seen here, is goitre. This forms a large tumor in the neck, for which formerly little could be done, as an operation was nearly always fatal. Such patients were obliged to go through life with a dreadful deformity, in the greatest discomfort, and were sometimes suffocated by pressure on the windpipe. In consequence of the introduction of the antiseptic method of Lister, which we owe to vivisection more than to any other agency, operations on the thyroid gland are now so common that at the German Surgical Congress in April of this year Professor Kocher, of Berne, has reported 2000 operations done by himself, with a mortality of only four per cent.

Very soon it was discovered that removal of the entire gland produced a curious effect. The face became bloated; the expression greatly changed, and the patient became more or less idiotic—that is, the condition known as myxœdema followed. This led to improvement in operations in several directions. First, in all those cases in which the tumor could be shelled out, as an English walnut is turned out of its shell, leaving a portion of gland tissue behind, this was done. The similar effects of the removal of the thyroid in animals were studied especially by Mr. Horsley. Surgeons then removed the thyroid gland from the neck of an animal and placed it under the skin of the same animal, and it was found that the disastrous results were avoided. After a number of experiments on animals there was good reason to believe that the disastrous effects of the operation which sometimes followed goitre could be avoided in man by the same procedure. Accordingly the thyroid gland of a sheep was transplanted in a number of instances under the skin, or in some cases into the abdominal cavity. In both cases there was improvement for a time; but eventually the majority of the cases suffered from cretinism or myxœdema, which may be described as a less severe form of the same disease. Finally in animals a study was made to determine how much of the gland must be left in order to prevent myxœdema, and now we are able to relieve patients from goitre and yet, by leaving enough of the gland, prevent any bad results following the operation.

These results led also to a careful study of the effects of giving an extract of the thyroid gland to human beings. Some of the most brilliant results that have ever been obtained in medicine have followed the administration of the thyroid extract to cretins in whom the disease had not been produced by operations for goitre, but arose naturally. In certain forms of goitre it has enabled us to relieve or even to cure without operation. In insanity and many other mental states it is used as a well established remedy, which in even a large percentage of cases is followed by great benefit and often by cure. In many other diseases also the thyroid extract has been used with the best results.

REMOVAL OF THE LARYNX.

Cancer of the larynx, or that part of the windpipe back of and just below the Adam's apple, is not at all uncommon. The only hope of such patients is in removing the entire larynx or voice box. Before attempting this for the first time on man, Billroth, of Vienna, and his assistant Czerny, now the distinguished

Professor of Surgery at Heidelberg, tested the operation on several dogs. Billroth then removed the larynx from his patient and saved his life. This operation has now been successfully repeated scores and scores of times as a result of these few experiments on dogs.

THE LUNGS.

A beginning has been made in the surgery of the lungs, but as yet we have not reached the point where we can say that we have attained entire success. In a number of animals parts of the lungs have been cut out with a view of discovering the possibility of cutting out diseased portions of lung, the seat of tumors, consumption and other disorders, and a few operations have been done upon man, with a fair percentage of success. Not uncommonly abscesses of the lungs which were perfectly inaccessible a few years ago have been reached and opened. Sometimes coins and other foreign bodies get into the bronchial tubes, and can only be reached through most difficult and dangerous operations. Several surgeons have experimented upon animals to determine the safest method of removing such bodies, but with only partial success. Is it not evidently our duty to devise new operative procedures and test them on animals first, and, when a reasonably promising one has been found, to apply it to man?

THE LIVER.

In 1890 Ponfick, of Germany, showed that in rabbits the removal of a quarter of the liver caused a slight deterioration in the condition of the animal; removal of one-half was followed by much more serious symptoms, which, however, passed off within a few days Even removal of three-fourths of the whole liver could be recovered from, but removal of more than this was always fatal. By killing the animal in which a small part had been removed at a suitable time, and studying microscopically the liver tissue at different periods of time after operation—a procedure manifestly only possible in animals—he showed that there was a reparative power in the liver, which before then was unknown.

Up to that date less than a dozen surgeons had operated on tumors of the liver. In only two of them was any considerable portion of the liver removed. After the paper by Ponfick, which showed how much could be removed, surgeons immediately operated with much more confidence, and removed considerable portions of the liver. Up to 1899 seventy-six tumors of the liver had been removed. Of these cases the termination of two was unknown; of the remaining seventy-four sixty-three recovered and eleven died—a mortality of less than 15 per cent. One who is not a surgeon can scarcely appreciate how differently the operation for tumor of the liver was regarded before and after Ponfick's experiments. Before that everything was marked by timidity; after that everything was marked by confidence, and all to the benefit of the patient.

THE SPLEEN.

The same story that has been told of the liver can be told of the spleen, though with much less good results. As a result of studies, partly by accident, in man (as when in consequence of a stab-wound or other injury a spleen would protrude through the wall of the abdomen, and would have to be removed), but chiefly as a result of the

careful studies of removal of the spleen in animals, beginning practically with Schindeler's experiments in 1870, we are now in a position definitely to say that in man the whole of the spleen can be removed, and he can not only survive the operation, but get along comfortably without any spleen. A very considerable number of such operations have now been successfully performed.

THE KIDNEY.

On August 2, 1869, Professor Simon, of Heidelberg, laid the foundation of the modern surgery of the kidney by removing a healthy kidney from a healthy woman. The reason for it was that in removing an ovarian tumor some time before he had been obliged to remove a part of the ureter (the tube leading from the kidney to the bladder), and to fasten the cut end to the skin. As a consequence of this the woman was in a most deplorable condition from the continual escape of urine over her person. After a number of unsuccessful attempts to close this external opening, it finally occurred to him that the only way to cure her was to remove the kidney on that side. Whether a human being would recover and could live with only one kidney was practically unknown. It is true that disease had destroyed one kidney in some patients and the other had gradually developed ability to do the work of both. Injury also had destroyed parts or all of one kidney, but deliberately to take out a healthy kidney from a healthy human being was an operation not only fraught with danger, but one before which all the surgical world up to that time had recoiled. No one had studied the effect on the remaining kidney and upon the heart. No one had carefully determined what was the best method of reaching the kidney—whether through the abdomen or through the loin from the back; what to do with adhesions and many other technical questions. All these had to be settled. Accordingly he experimented on a number of dogs; decided that from these indications a human being could live with only one kidney; studied on the cadaver the best way of doing the operation, and on August 2, 1869, removed this healthy kidney through the loin and saved the patient's life and made her perfectly comfortable. She died in 1877, after eight years of healthy life.

As I have said, these new experiments laid the foundation of the modern surgery of the kidney. Now hundreds of kidneys have been removed successfully. Finding this operation so feasible, surgeons were led to practice other operations; some hundreds of abscesses in the kidney have been opened; scores of stones have been removed from the kidneys; floating (i. e., loose) kidney has been sewed fast in hundreds of cases; many cases of tuberculosis of the kidney have been relieved or cured; tumors of the kidney are successfully attacked; even the cut ureter has been spliced and stones removed from it. In a word, Simon's experiments on a few dogs opened to us a new domain in surgery which until then was wholly unknown. Would it not be gross cruelty to man to prevent such beneficent researches?

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PART 11

THE STOMACH.

Were I limited to the progress of the surgery of the stomach alone by vivisection there would be quite enough material for this entire paper. Until 1875 practically there was no surgery of the stomach. As occasional Cæsarean sections have been done in the past, so occasional operations on the stomach were done when the surgeon was obliged to do them. Now, however, it is a matter of routine procedure, to the vast benefit of the human race. Had vivisection contributed nothing else to the progress of surgery than its services in the surgery of the stomach, this alone would be sufficient to justify it. I may quote from the Cartwright lectures which I gave before the College of Physicians and Surgeons in New York in 1898:*

In 1875 Tschertneisky-Barischewsky cut out a piece of the intestines in 35 dogs, with 29 recoveries—a startling result when compared with the former fatality of such operations. This was the starting point in the new gastro-intestinal surgery. The next year Gussenbauer and Winiwarter cut out a piece of the stomach in only seven dogs. We scarcely can appreciate at this day, though these experiments are so recent, how many new questions had to be answered. After their first unsuccessful experiment they naively remark that certain facts were established by the experiment, among them, "that the surfaces of the stomach have a real tendency toward union by first intention, . . . just as do wounds of the skin." (!) Whether this would be correct of man as well as of animals they admitted was as yet uncertain. Another point settled by the experiment was "that there was no digestion of the mucous membrane in the neighborhood of the wound." Their second experiment was followed by recovery, and showed not only that such an operation could be successfully done, but that the narrowing caused by the scar did not interfere with the

*In quoting this I have popularized some of the medical terms there used.

functions of the stomach, either as to its movement or its secretion of the digestive juices, and that the removal of the pylorus was not followed either by the too early escape of the food into the intestines, or by the reflux of the intestinal contents into the stomach. The dog was killed five months later and the post-mortem showed no contraction, by reason of the scar, and no digestion of the edges, and his perfect health after the operation showed that the movements of the stomach and its digestive functions had not been interfered with. Then, again, the question whether catgut or other suture material was the best, and what kind of a knot and what kind of a suture would best answer were subjects of debate. . . .

Our anti-vivisection friends, who so often declare that experiments upon animals have never contributed anything to the progress of surgical science, may well be challenged to account for the remarkable progress in the surgery of the stomach which immediately followed these fruitful experiments. The dogs that died did not die in vain. They showed the correct methods and indicated errors in technic, and directly led up to the modern surgery of the stomach and the intestine in man, as follows: In the very same year, 1876, Hueter cut out a part of the bowel, though without success. In 1877 Czerny for the first time sewed up the intestine and dropped it into the abdominal cavity, with recovery; followed almost immediately by Billroth, who did the first successful suture of the stomach and total removal of a portion of the bowel. In 1878 Forelli operated for a wound of the stomach, and in 1879 Cavazzani removed a portion of the stomach for tumor. In the same year Pean did the first removal of the pylorus. In 1880 Rydygier did the second, and in 1881 Billroth did the third and first successful one, without a knowledge of the preceding operations.

Then followed various operations on the stomach to which I will allude later, and finally the successful removal of the entire stomach. It is quite impossible to give the details of all the various operations now done on the stomach and indicate minutely the part that vivisection has had in developing this extraordinarily successful branch of modern surgery. Suffice it to say that among them are the following, all of which owe more to vivisection experiments than to any other single agency:

In cancer of the œsophagus or in the constriction of the œsophagus, which so often follows the accidental or intentional swallowing of lye or acids, etc., so that no food can get into the stomach, we now open the abdomen, open the stomach, introduce a tube or construct a passageway into the stomach, and feed the patient through this outside œsophagus, as it were. In case the narrowing of the œsophagus is not from cancer the patient can live his natural span of life. In case of cancer his remaining days are rendered relatively comfortable, since the operation prevents his starving to death. When we have cancer at the opposite end of the stomach (the pylorus), so that the food, though it can be swallowed, cannot get out of the stomach, one of two courses is followed, both of which have been carefully studied in the lower animals and then adapted to man. First, the portion of the stomach and bowel involved in the cancer is cut out and the bowel united to the stomach directly, or, in other cases, an opening is made in the stomach and one in the bowel lower down, and the two openings are sewed together, thus allowing the food to pass from the stomach directly into the bowel beyond the cancer. The mere question of how the stomach and bowel shall be most successfully united in these cases, particularly the best method to prevent fatal leakage, has required very many series of experiments, especially in this country, by Senn, Abbe, Brockaw, Ashton, Murphy and others. As a result of their labors sometimes we have learned how not to do the operation be-

cause of unexpected difficulties; sometimes how to better our procedure, until now we are in possession of satisfactory methods, as has been proved by the successful operations on man many times over. Even the sewing together of the stomach and bowel alone had been done up to 1898 in 550 cases which have been published. I have no doubt that since then this number has almost been doubled. The mortality of this operation from 1881 to 1885 was 65.71 per cent.; from 1886-90, the mortality had fallen to 46.47 per cent.; from 1891 it had again fallen to 33.91 per cent., and recently in twenty-seven cases an Italian surgeon (Carle) has had a mortality of only 7.4 per cent.

Moreover, the experiments on animals, having shown how safe various operations are, have emboldened us to enlarge the sphere of our operations and do others that were before not dreamed of—a good instance of the partly indirect good results from vivisection. A brief enumeration of some of the various operations done upon the stomach, together with their mortality, is as follows:

(1) Where the stomach is bound down by adhesions (which often produce the most serious digestive disturbances, destroying comfort and even threatening life), we now open the abdomen, cut or tear the adhesions, and practically all of the patients recover.

(2) Where there are foreign bodies in the stomach (or in some cases foreign bodies that have stuck in the œsophagus low down, near the stomach), we open the stomach, remove the foreign body (often inserting the entire arm to reach it in the œsophagus), sew up the stomach and the abdominal wall, and the patients generally recover. In some cases as many as 192 staples, buttons, screws, horse shoe nails, etc., weighing over a pound and a half, have been removed, and the patients have recovered.

(3) Where the œsophagus has been narrowed by the swallowing of lye, etc., instead of making a permanent opening in the stomach (as before described), sometimes by having the patient swallow a perforated shot which will carry a string down into the stomach, we can open the stomach temporarily, seize and draw out the shot, attach a conical dilator to the string, and, after having dilated the constriction of the œsophagus, remove the string, sew up the stomach and the abdominal wall and cure the patient permanently.

(4) We now open the stomach purely to explore it and find out whether or not there is serious disease. This has enabled us in many cases to relieve illness which otherwise was incurable. Nearly all of these patients recover from the operation.

(5) The permanent opening in the stomach through which we can feed a patient I have already described. It was first proposed in 1837. It was first done in 1849. From then until 1875 twenty-eight cases were operated on, with twenty-eight deaths! It seemed almost as though the operation must be abandoned when, in 1875, the first operative recovery occurred. From then until 1884 in 163 cases there were 133 deaths—a mortality of 81.66 per cent. At the present time the mortality is only about 25 per cent. in cases of cancer, and in the non-malignant cases not over 10 per cent.

(6) As I have indicated, in certain conditions we make an opening in the stomach and another in the bowel and sew

the two together. In some cases of ulcer of the stomach, which cannot be cured by medical means, this gives wonderful results, both as to comfort and cure. The operation was first done in 1881, with a mortality decreasing from 65.71 to 33.91 per cent. in general, and in the statistics of single surgeons to only 7.4 per cent.

(7) The first removal of the pylorus with union of the bowel and stomach was done in 1879. The mortality was very great, and still is large, ranging from 27.2 per cent. in simple cases to 72.7 per cent. when there are extensive adhesions.

(8) When the pylorus is simply narrowed, but is not the seat of cancer, we make an incision in its long axis, seize the edges of the incision at the middle, draw them out at right angles to the line of the incision, and by sewing them in this position we widen the opening of the pylorus. This was first done in 1886. Up to 1894 the mortality was 20.7 per cent. Recently Carle has reported fourteen cases, with a mortality of only 7 per cent.

(9) In not a few disorders the stomach is dilated to nearly two or three times its normal size. In these cases we now take a "tuck" in it, as was first done in 1891. Up to three years ago fifteen such operations had been done, with only one death.

(10) When the stomach, instead of being dilated, is displaced, we sew it fast, and practically in all cases recovery follows.

(11) Sometimes the stomach is divided into two parts, like a dumb-bell with a very short handle. The first operation for relieving this condition was done in 1893 by making an opening in each half of the stomach and sewing the two openings together. Up to this year over forty operations have been done for this condition, with only nine deaths.

(12) Tumors of the stomach other than cancer are rare, but since 1887 at least seven cases of tumor have been cut out, of which six have recovered.

(13) Partial removal of the stomach finally led to its complete removal, of which over a dozen instances have been reported, with a recovery of somewhat more than half. Nearly all, however, have died from recurrence.

Some of the above operations are not the direct result of experiment upon animals (as, for instance, the taking of a tuck in the stomach); but they are the indirect result, first, through the antiseptic method, which itself is the child of vivisection, and, secondly, because through our experience in other operations we have been led to perform totally new ones. It is the same in other sciences. If we were still dependent upon the old "air pump" worked by hand we should have no lighting by the incandescent bulb of to-day, for this is dependent upon a cheap method of making an almost complete vacuum. This is a wholly unexpected and indirect result of improvement in air pumps as one of the chief factors of progress.

THE INTESTINES.

Very much the same story can be told of the surgery of the bowel. Indeed, the surgery of the stomach involves largely that of the bowel. I need, therefore, only recall a very few points. When a tumor or cancer exists in the bowel, of course, in a little while it obstructs the passage of the intestinal contents; and if this obstruction becomes

complete and is not quickly removed the patient must necessarily die. As a result of many experiments upon animals (more especially by Senn, Parkes and other American surgeons) we now know how to deal with this condition. First, if the tumor or cancer can be removed it is cut out entirely, and the two ends of the bowel are united. Our present successful means of uniting them are a result of most laborious researches by experimentation upon animals to discover the best method of doing this otherwise perilous operation. The slightest leakage of intestinal contents produces a fatal peritonitis. Where the cancer cannot be removed, in order to prolong the patient's life and lessen his terrible pains we make an opening above the obstruction and another one below and sew the two openings together. Here again many experiments were needed to determine whether an animal could live with the intestinal contents thus "side-tracked," and if life could be maintained, what was the best method of doing the operation.

In gunshot wounds of the intestines, which formerly were among the most fatal of all accidents, we now can rescue a very large percentage of the patients. During the civil war practically almost every case of perforation of the intestine by gunshot died. To see whether something could not be done to remedy this frightful mortality Gross many years ago performed some experiments to determine the best treatment of such wounds. Later Parkes etherized a number of dogs, shot them, opened the abdomen and treated the wounds in various ways; and in consequence of this and other series of experiments, at the present time many instances of recovery have been reported in which multiple wounds even to the number of seventeen have been found closed by methods determined by vivisection to be the best, and the patients have recovered. To reach this result it had to be determined by accurate observation on animals what was the best method of closing such wounds; what material is the best for use as a thread; under what conditions it would be needful, instead of closing the wound, to cut out the injured portion of the bowel and unite the two ends; how long after perforation occurred was the best time to operate, and many other such questions too technical to mention here.

In typhoid fever and in ulcer of the stomach also sometimes a perforation similar to the hole made by a bullet occurs, and the contents of the intestines or of the stomach are poured out into the abdominal cavity. Of course, every one knows that if this went on for a brief time death would necessarily follow. In the lower animals we cannot produce exactly the conditions following gastric ulcer and typhoid fever; but, in consequence of the knowledge acquired by experimenting upon gunshot and incised wounds of the stomach and bowel in the lower animals, in 1884, we finally woke up to the fact that a perforation after such an ulcer, either in the stomach or in the bowel from typhoid fever, ought to be closed. In 156 cases of such perforation of the stomach operation has been done, and the recoveries have been 46.80 per cent. But in the last 54 of these operations done from 1896 to 1898 the percentage of recoveries had risen to 64.82 per cent. In 158 such operations done for perforation of the bowel in typhoid fever collected in

1898 the recovery rate was 23.41 per cent. Since then it has risen to over one in three, and ultimately, I believe, one-half of such patients will be saved. It must be remembered that in such perforations of the stomach and bowel every patient would die were no operation done. To save one-half or even one-third is a surgical triumph.

I have several times alluded to cutting out a portion of the bowel and uniting the two ends. This involves a number of problems which ought not, and, in fact, cannot, be studied in man because of the fact that it is wholly inadmissible to test such operations (which always involve life) on man when they can be tested accurately and more quickly by experiments on animals and without involving human life.

I have stated that by many experiments on animals we have now reached a satisfactory solution of the problem how the two ends of the bowel are best sewed together. But one other question was still unanswered—how much of the bowel could be removed and yet life be preserved. A similar question, we have seen, has been answered in respect to how much of the liver could be removed by Ponfick's experiments. How much of the bowel could be removed was a most important question. We would all presume that a few inches, possibly even a foot or two, might be removed without danger; but when we remove a larger portion we cut down the digesting and absorbing surface to such an extent that it is a question whether the patient can still live. This has been determined upon animals, and then, as occasion required us to decide the question, in man. As a result of the knowledge derived from animal experimentation I saw four years ago in Montreal a man from whom Shepherd had removed over one-third of the entire length of the bowel (eight feet) which was involved in a large tumor; and yet the patient was in capital health a long time after the operation.

HYDROPHOBIA.

The search for the germ of this dreadful disease has as yet been fruitless; but happily the search for the means of prevention has been crowned with success. Of every hundred persons bitten about fifteen contract hydrophobia, and of those bitten on the head and face at least 80 per cent. die of hydrophobia. The Pasteur treatment, which is entirely the result of animal experimentation, by preventing its occurrence, has reduced the mortality to less than one per cent.; and yet the establishment of Pasteur Institutes for the benefit of the human race has been resisted most strenuously by those opposed to vivisection.

TRANSPLANTATION OF BONE.

In 1867, Ollier, a celebrated French surgeon, who recently died, by experiments on animals showed that the membrane which covers the bones (the periosteum) could be peeled off a bone and transplanted to a distance into the tissues of the same animal, or even of another animal, and that it would there live and produce new bone. These experiments, very crudely described in these few words, have been extraordinarily fruitful in several directions.

First, in certain cases it is necessary to remove diseased or dead bone. These experiments showed us that if in removing the bone the periosteum was carefully guarded and left behind it would reproduce the bone. In some cases in which the lower jawbone has died as a result of phosphorus poison in the em-

ployes of phosphorus match factories, the dead bone has been removed, but the periosteum has been preserved and a new jawbone has been reproduced. Another result has been that, instead of amputating, for example, an arm when the elbow is diseased, we can remove the bone and by preserving the periosteum can preserve a more or less useful joint.

In other cases a certain area of bone, as, for instance, in the skull, is chiseled loose or otherwise separated from the surrounding bone excepting for an inch or two at the portion where the chief blood supply enters the flap. The bone is then forcibly broken at this unchiseled portion and turned back, the periosteum and scalp acting as a hinge. When the tumor has been removed, the abscess opened, or other needful operation done, the trap door is simply closed by replacing the flap, the scalp sewed in place and the integrity of the skull is restored. One can see that this is an immense advantage over having a great hole left in the side of one's skull.

In some cases, in which, in consequence of accident or abscess, a large hole already exists in the skull, we either chisel off bits of adjacent bone or take pieces of bone from one of the lower animals and successfully fill this opening.

Again, in certain cases, for example, in which the jaw has been fractured, a bit of the bone has been chiseled loose from the patient's jaw and has been grafted in place as a bridge between the two fragments, so relieving the deformity or remedying an otherwise incurable fracture.

Again, a certain small number of children are born without any bone at the back of the spine in the neck or the loin (spina bifida). Through this opening the membranes of the spinal cord protrude and form a tumor which, if untreated, in most cases proves fatal. We now operate most successfully on many of these cases, and in suitable cases either chisel loose a bit of adjacent bone and transplant it, so as to close the opening, or in other cases take a bit of bone from one of the lower animals to fill the opening and cure the patient.

Again, in certain cases of fracture of the arm bone (humerus) the nerve going to the muscles on the back of the forearm, which winds close around the bone in a spiral, is torn in two; these muscles are paralyzed, and the patient has what we term "wrist drop," so that the hand is useless. In such cases the knowledge derived from two different series of experiments comes to our aid to enable us to remedy the trouble. First we find the two ends of the broken nerve, freshen these ends, unite them, and in many cases can change a useless hand into a useful one; but if so much of the nerve has been destroyed that the two ends cannot be brought together we now deliberately remove an inch or two of the arm bone, thus shortening the arm so as to bring the two ends of the nerve together, and in a good percentage of cases we can again restore the hand to usefulness after months and occasionally even after years.

A still more remarkable transplantation of the bone is accomplished in some operation on the skull. In some cases it is necessary to remove a button of bone which may be an inch and a half or two inches in diameter in order to do an operation on the brain. The operation which has necessitated this removal of bone may require an hour

and a half or two hours. If we want to replace the bone so as not to leave an opening in the skull through which the brain may easily be dangerously injured, we put it in a basin of hot salt solution or weak antiseptic solution, and by keeping it at a proper temperature, at the end of the operation, when it has been totally detached from the body for so long a time, we replace it and its vitality is not lost.

All of these various operations (and others which I have not time to describe) done on bone, to the immense advantage of our patients, are the direct or remote results of the experiments of Ollier and others on the transplantation of periosteum and of bone. The indirect results are quite as valuable, and sometimes more valuable, than the direct results of such experiments.

An illustration of the indirect results of Ollier's experiments is shown in the transplantation of the skin. One of the oldest operations in surgery is the making of a new nose. When the nose has been lost a suitable shaped flap was cut on the forehead, leaving a sufficient uncut base for a proper blood supply so that the flap would not undergo gangrene. The flap was then turned by twisting it on its base and was sewed in place where the nose had been. The experiments of Ollier and his successors showed, however, that periosteum, and even so dense a structure as bone, could be entirely detached from the body for a long time and yet not lose its vitality. Hence we now transplant bone as well as skin to make firm instead of flabby noses. This has led us of late years to apply the same procedures to the skin, and enables us now to do far more extensive and more successful operations than would otherwise have been possible. The first method tried in man was that of Reverdin, of Geneva. He cut little bits of skin only as big as a pin's head from the arm or the thigh, not quite skin deep, and planted them on any raw surface which did not heal readily. These grafts under proper treatment adhere and form new centres from which healing of the wound takes place. Emboldened by this, Krause and other surgeons have taken very large pieces of skin, including often the whole thickness of the skin, and transplanted them. For example, in some cases of extensive cancer in which a very large portion of skin must be removed, now, while the patient is under the influence of the anesthetic, we take strips of skin an inch wide and several inches long from the thigh, or, in other cases, from another person who is willing to give up a portion of his skin. These pieces are immediately placed on the raw place left by the removal of the tumor, and as they do not lose their vitality but grow fast to the tissues under them, the wound is healed almost immediately, instead of taking a long time for the slow formation of a scar.

One of the most difficult of all wounds to heal is an extensive burn, such as is produced by the clothing catching fire. In these cases large surfaces of the skin on the chest or the abdomen slough off, resulting in great ulcers. These sometimes take months, sometimes years, to heal, and in not a few cases never heal, no matter what is done. Now, as a result of our experience, first with the periosteum and bone and then with small bits and then larger bits of skin, we transplant strips of skin as just de-

scribed, and heal such wounds in a very short time. One sees in the newspapers every now and then accounts of some woman whose long hair has been caught in machinery and almost all of the scalp torn away. These wounds are healed by transplanting skin in a similar manner.

THE BLOOD.

We are at present only just beginning to appreciate how much we can learn from examination of the blood, especially by new methods lately introduced. Almost every intelligent person knows that the blood consists, roughly speaking, of a fluid in which float small circular disks, about 1-3000 part of an inch in diameter, called the red blood cells. In addition to these there is in the blood another kind of cell called the white blood cell. The red blood cells are made up chiefly of a substance called hemoglobin, which gives the color to the blood. Some of the investigations, which are really only at present at the beginning of their usefulness, are as follows. They are good illustrations of how inductive science begins by ascertaining facts. If they are valueless they are disregarded; if of value they are studied still further. It is not unlikely that the blood may soon be one of the most fruitful sources of the knowledge by which surgery may profit greatly:

First, the number of white blood cells. It is found that in case inflammation results in an abscess the number of white blood cells is increased several times. Ordinarily in a little cube of blood one millimeter (the twenty-fifth part of an inch) on each of its sides the number of red blood cells is about four to five millions, and the number of white blood cells is 8000 to 10,000.

If one has an abscess the white blood cells as a rule will rise to 15,000, 20,000, 25,000 or more to the cubic millimeter—a condition that we know scientifically as "leucocytosis." In certain cases when it is a question whether an abscess exists (as, for instance, in the brain, in the liver, and other parts of the body in which the diagnosis is very difficult to make) if the leucocytosis or its absence will show us absolutely that there is or is not an abscess present it would be of the greatest help.

Again, in typhoid fever the pain and tenderness exist just above the right groin. In appendicitis the pain and tenderness exist in the same region, and in not a few cases it is extremely difficult to distinguish between these two diseases. Especially is this true at the beginning of such an illness, just when it is most important to make the right diagnosis and institute the correct treatment. If the presence of leucocytosis will show us distinctly that it is appendicitis, and the absence of leucocytosis that it is typhoid fever, an immense gain in accuracy of diagnosis, and, therefore, of the proper treatment, will result. To open the abdomen, if it is typhoid fever (without perforation), would be a dreadful mistake; not to open it, if it is appendicitis, would be, as a rule, equally wrong treatment. If the leucocytosis is a sure guide we cannot learn it too quickly. It seems to me very reasonable, therefore, that experiments should be made in the lower animals by producing abscesses and determining whether under many varying conditions leucocytosis is always present when there is an abscess and always absent when there is no abscess.

Second Hemoglobin.—The hemoglobin, which makes up the bulk of the red

blood cells, is the means by which oxygen is carried to all parts of the tissues. Whenever an anesthetic, such as ether or chloroform, is given, the amount of hemoglobin is distinctly diminished, and by this means the oxygenation of the blood is hindered. In certain conditions of the system the percentage of hemoglobin is diminished to 60, 50 or even as low as 25 of the normal. If an anesthetic is given to a person with an already diminished percentage of hemoglobin this percentage is still further diminished, and the oxygenation of the blood still further hindered. If, then, the percentage of hemoglobin is very small before an operation the danger of giving an anesthetic is very marked; if the hemoglobin is as low as 30 per cent. it is very likely that the patient may die upon the table irrespective of the operation, simply because the anesthetic reduces the hemoglobin to such a point that the blood does not absorb enough oxygen to carry on life. Some authorities have stated that we ought never to give ether or chloroform to a patient whose hemoglobin is below 50 per cent. Others have placed the limit as low as 30 per cent. Surely this subject, which is very recent and about which we know up to this time very little, ought to be investigated with the greatest care in animals rather than to decide the question by sacrificing life by venturing to give an anesthetic to patients whose hemoglobin is at so low a point as to be inconsistent with safety.

Other recent researches are those on the temperature at which the blood freezes and the lapse of time after the blood is drawn from the body before it coagulates—that is, clots. A small portion of blood drawn by a prick of the finger enables us to determine these four conditions—i. e., (1) the presence or absence and degree of leucocytosis; (2) the percentage of hemoglobin; (3) the freezing temperature of the blood, and (4) the coagulation time of the blood. We are beginning to see that these last two as well as the first two will probably prove of the greatest value in reference to surgical operations. Hence we ought to learn accurately and quickly all the facts in the case by experiments upon animals, and so avoid dangers to human life of which until lately we have been quite ignorant.

These would include experiments upon animals fasting, or after feeding; after being bled; after surgical operations have been done upon them; after an anesthetic is given to them; when the anesthetic is administered for a short time, for a longer time, for a very long time, for a time long enough to kill them, in order to determine what the effect of the anesthetic is in fatal and non-fatal doses. It is of the utmost importance that we should know exactly and speedily the result of all these conditions. If we are debarred from learning them by experiment on animals, then the human race must go without the knowledge we seek, saving as it is revealed to us from time to time by studying slowly and inexactly the results in man. With certain modifications due to the slight differences between man and animals the conclusions drawn from experiments on animals apply to man.

Let me give one instance which confronts the surgeon not infrequently. An abdominal section is occasionally followed by very great and, it may be, dangerous and alarming depression. One of the most difficult things to determine

in some cases is whether this condition is due to the shock of the operation or to internal hemorrhage. This hemorrhage differs from that which may follow an amputation or removal of a tumor from the neck, etc., by the fact that it is concealed within the abdomen, and its existence can only be inferred. If the patient is suffering from shock, stimulation, heat, quiet, certain drugs, etc., will be resorted to to enable him to recover. If it is due to internal hemorrhage, we must instantly reopen the abdomen and tie the bleeding vessel. To do the latter operation when the patient is only suffering from shock might prove fatal; not to do it, if hemorrhage is the cause of the depression, is certainly fatal. No one not a surgeon can appreciate the anxiety, the careful weighing of evidence, the intense longing for some positive means by which a correct diagnosis may always and surely be made, which every surgeon feels in such an emergency.

It is possible that by examining into the presence or absence of leucocytosis, by determining the percentage of the hemoglobin, or possibly even the coagulation time and the freezing temperature of the blood in a number of operations in human beings, we might be able positively to determine the difference between shock and internal hemorrhage, but only after making many blunders, each of which would cost a human life. In an animal we can open a blood vessel in the abdomen and let it bleed for a longer or shorter time, and determine positively the leucocytosis, the hemoglobin, etc., the animal meantime suffering nothing because it would be under an anesthetic. Which is the right, which the kindest, which the most humane way of finding out the truth? This is an illustration of the harmlessness to animals of such experiments and their priceless value to human beings.

EXPERIMENTS TO ENABLE US TO MAKE A RELIABLE AND SPEEDY DIAGNOSIS.

In some cases in which the diagnosis is difficult, or may require considerable time, experiment upon animals aids us greatly, and so is of immense value to man. Thus in supposed anthrax, or wool-sorter's disease, a most dangerous malady, by inoculating a guinea pig with the discharge the diagnosis can be cleared up quickly and proper treatment instituted. If a case suspected to be one of bubonic plague arises the diagnosis can be established within 24 or 36 hours by a similar injection into a rat or a guinea pig, the apprehensions of a community (to say nothing of the patient and his friends) relieved and the greatest damage to its commerce averted by discovering that it is not the dreaded pestilence, or, if it is the plague, by showing the necessity for most stringent measures of prevention. I do not think any community will or ought to allow sympathy with the unavoidable suffering of a few rats or guinea pigs to weigh in the balance for a moment against the safety of many human lives or the ruin of large business interests.

An amusing instance of how sentiment gives way before affection and facts occurred not long since in England. The brother of the Duke of Newcastle was bitten by a dog supposed to be rabid. The Duke was a Vice President of the Anti-Vivisection Society, but knowing that whether the dog was rabid or not (and, therefore, whether his brother was in danger or not) could only be settled by inoculation experiments upon animals,

he took the dog to Mr. Horsley, in London, and had the experiment done.

By similar means anthrax and actinomycosis (or lumpy-jaw, which spreads to man as well as to herds) among cattle are diagnosticated and eradicated; glanders in horses is recognized and stamped out and tuberculosis in cows is eradicated, not only preventing its spread to healthy cattle but through the milk to many human beings, especially young children, whose chief diet must be milk.

By similar experiments on animals chicken cholera, hog cholera, Texas fever and many other diseases of cattle, sheep, horses, hogs, poultry and other animals have had their causes discovered and the means of prevention or of cure demonstrated. The Reports of the Bureau of Animal Industry at Washington enter into these in detail. Surely the poor animals who have benefited so greatly from such experiments should pray to be saved from their friends if these beneficent researches are to be prohibited.

I often wonder what would have been the influence on surgery if the young man who first took ether in the Massachusetts General Hospital on October 16, 1846, had died. Morton, it is true, had experimented on some dogs first, but, as we now view it, very inadequately. Had this patient died, would not the use of ether have been deferred for years, possibly even till now, and meantime the human race all over the world have gone on suffering the horrible tortures of the pre-anesthetic days and all our modern progress in surgery have been prevented? I hardly ever look on my patients in the blessed ether sleep without being impressed with the confident audacity of the earlier operators who dared to induce a sleep so like that of death when they must often have asked themselves whether the patient would ever waken or whether this was not the first stage of the never-ending sleep.

If the sacrifice of the lives of even a considerable number of animals enables us to reach the benevolent purposes a few of which I have described, is it not plainly a moral duty to perform them so as to obtain this knowledge? Is it not wrong to hinder such benevolent researches? Especially is it not wrong so to hinder research when, in the vast majority of instances, animals suffer little or nothing? In almost all experiments not only can an anesthetic be used, but in all involving difficult and delicate operations it is essential to do so; for it is impossible to do such an operation on an animal struggling from pain. Not only, therefore, does sentiment lead the vivisectionist to spare the animal all the suffering that is possible, but scientific accuracy points in the same direction. A very few experiments, principally those on the nervous system which require us to determine the presence or absence of sensation, cannot be done with an anesthetic; but these experiments are few and far between. Some experiments also (for instance, those on lock-jaw, to which I have already alluded) by producing the disease, necessarily make the animal suffer; but if by the suffering of a few animals, human beings suffering from lock-jaw can be cured, or, still better, if we can learn the cause of the disease and so can prevent it from attacking human beings, is it not worth the suffering? The infliction of suffering is not cruelty. If one dear to us meets with an accident far away from surgical

aid and we spur a horse to the utmost, so that finally it drops dead in the frantic effort to bring surgical assistance, I am sure no one would accuse us of cruelty, although we had inflicted torture upon the horse. So this infliction of pain on a small percentage of animals experimented on is not cruelty, but is the greatest kindness to other animals and to a much higher animal—man himself.

I have been able in this paper only to select a few illustrations of the progress that surgery has made by experimentation on animals. Practically, as I said at the beginning, nearly all of these have occurred during my professional life, and I speak, therefore, of what I know. Although I myself am not a vivisectionist, yet I could not do the work I do every day and accomplish results I do were it not for just such work, of which I take advantage. In view of these facts, therefore, how unwise it would be to restrict and still more to abolish such life-giving and pain-saving results of vivisection, especially when the animals themselves benefit from these experiments fully as much as man. I have not referred to any of the older experiments, such as those remarkable experiments of Jones on the methods of tying blood vessels in the early part of the last century, nor of Sir Charles Bell's experiments by which he determined the functions of the two different roots of the nerves just as they emerge from the spinal cord, nor of the circulation of the blood as discovered by Harvey. All these are fundamental; and without the knowledge derived from them we should be a century or more behind where we are now. I have preferred rather to take modern instances with which I am personally familiar in order to illustrate the subject which I have been asked to describe. I cannot believe that any unprejudiced, fair-minded reader will not agree with me that such humane purposes should be fostered and not hindered; should be encouraged and not abolished.

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